MSC Guidelines for Review of Structural Plans for Wooden Vessels

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References

a. Title 46 CFR Subchapter R, Subpart 167.20 - Hull Requirements, Construction and Arrangement of Nautical School Ships, Subpart 168.05 - General Requirements, Subpart 169.300 - Construction and Arrangement
b. Title 46 CFR Subchapter T, Subpart C - Hull Structure
c. 1997 ABS Guide for Building and Classing High-Speed Craft
d. 1986 ABS Guide for Building and Classing Offshore Racing Yachts
e. 1978 ABS Rules for Building and Classing Reinforced Plastic Vessels
f. 1943 ABS Rules for Building and Classing Wood Vessels
g. Lloyd's Register Rules and Regulations for the Classification of Yachts and Small Craft
h. Navigation and Inspection Circular No. 7-95: Guidance on Inspection, Repair, and Maintenance of Wooden Hulls
i. WOOD: A Manual for it's Use as a Shipbuilding Material, Volumes I through IV, Department of the Navy, Bureau of Ships, 1957,

Disclaimer

These Guidelines were developed by the Marine Safety Center staff as an aid in the preparation and review of vessel plans and submissions. They were developed to supplement existing guidance. They are not intended to substitute or replace laws, regulations, or other official Coast Guard policy documents. The responsibility to demonstrate compliance with all applicable laws and regulations still rests with the plan submitter. The Coast Guard and the U.S. Department of Transportation expressly disclaim liability resulting from the use of this document.

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Structural Standards

Subchapter T

Lloyd's Register of Shipping Rules and Regulations for the Classification of Yachts and Small Craft is the standard adopted by reference in Subchapter T for the design and construction of wooden small passenger vessels. Direct reference to the Lloyd's Rules is based on the familiarity that Coast Guard inspectors and technical personnel have with reviewing a vessel designed to this standard. In general, all wooden small passenger vessels must be built to the Lloyd's Rules. These Rules specifically address carvel, cold molded, double, lapstrake, single skin plywood, and strip planked vessels. Since wood has seen such a decrease in its popularity and use, however, Lloyd's Register no longer publishes this standard. The fact that a standard is no longer published does not prevent it from being used to demonstrate regulatory compliance. If the designer does not have access to these Rules, or the Rules do not address the vessel's specific construction/planking type, the designer may submit for MSC review a systematic analysis based on engineering principles that demonstrates the vessel's structures have adequate safety and strength (§177.340). A short discussion on alternative structural standards that can form the basis of a "systematic analysis" is provided as an attachment to these Guidelines.

Subchapter R

Public nautical school ships are prohibited from being constructed of wood or wood laminates (§167.20-1).

Civilian nautical school ships must be built to the same structural requirements as similar sized passenger vessels (§168.05-1).

Sailing school vessels must be built to the structural design standards established by a recognized classification society (§169.309). Sailing school vessels that carry more than 100 persons or have overnight accommodations for more than 49 persons are prohibited from being constructed of wood or wood laminates (§169.311).

Classification Society Review

Vessels Reviewed for Classification

The MSC considers the structural plan approval by a recognized classification society for the purpose of classification as sufficient demonstration of compliance with the regulations. Any plans of a vessel classed by a recognized classification society and submitted to the MSC will be returned without action stating this policy.

Vessels Reviewed for Load Line Assignment

The MSC considers the structural plan approval by an assigning authority for the purpose of load line assignment as sufficient demonstration of compliance with the regulations. Any plans reviewed by an assigning authority for this purpose and submitted to the MSC will be returned without action stating this policy. Please note that a load line review is much less extensive than a classification review. In a load line review, the assigning authority reviews only the major external strength members and ignores many structural components such as internal bulkheads that are reviewed if a vessel is seeking classification. Plans of structural members not reviewed by the assigning authority must be submitted to the MSC for review and approval.

Vessels Reviewed By Class Societies for Other Purposes

The MSC considers the structural plan approval by a recognized classification society as sufficient demonstration that the vessel's structures have adequate safety and strength in accordance with Title 46 CFR 177.340.

General Review Guidance

Documentation

Check that the following items are included in the submittal package:

- A detailed list of all plans noting what action is desired (approval, information only, etc.)
- A general description of the vessel and its functions such as: hull planking, method of attachment, length overall, length between perpendiculars, breadth, depth, block coefficient, estimated lightship and draft, load line draft, vessel speed, wave height vs. speed relationship (if applicable), service limitations, identification of novel designs and/or connection details requiring direct analyses, anticipated route, and types of cargo and number of passengers to be carried.
- If the vessel is classed: Ensure that the MSC and the cognizant Officer in Charge, Marine Inspection (OCMI) receive copies of the classification society's approval letter(s). The OCMI must also receive copies of the classification society's approved drawings for their use in the inspection and certification process.
- If the vessel is load-lined: Ensure that the MSC receives a copy of all structural plans not being reviewed by the classification society. In addition, ensure that the MSC and the OCMI receive copies of the approval letter(s) for the plans reviewed by the classification society. The OCMI must also receive copies of

the classification society's approved drawings for their use in the inspection and certification process.

- If the vessel is not classed or load-lined but the hull structure has been reviewed and approved by a classification society for other reasons: Ensure that the MSC receives the class society's approval letter and approved drawings.

Materials

Check that the following information is included in the submittal package if applicable:

- **Wood Materials:** Specifications that include the species, density, grade, specific gravity, moisture content and corresponding mechanical properties (modulus of rupture, modulus of elasticity, tensile strength parallel/perpendicular to grain, and compressive strength) of all plywood and timber members used.

- **Wood Preservatives:** Specifications that include its type and its effect on varnish, paint coatings, and synthetic resins.

- **Wood Adhesives:** Specifications that include the glue type and its compatibility with any wood preservatives used.

- **Fastener Materials:** Specifications that include its type (screw bolts, drift bolts, carriage bolts, wood screws, lag screws, or nails), composition, physical properties, corrosion resistance including its compatibility with the materials being fastened or insulation used, and a discussion on its suitability for the intended service.

- **Fiberglass Reinforcements:** Specifications that include the fiber type and form, weave, fiber orientation, weight, physical data, and mechanical properties of all fiberglass reinforcing materials used.

- **Resins:** Specifications that include the types and cured mechanical properties of all resins and gel coats used, as well as the type and amounts of catalyst, accelerators, hardeners and other additives.

- **Core Materials:** Specifications that include the material type, density, and mechanical properties of all cores used.

- **Laminates:** A laminate schedule for each laminate used in the design that includes the layup procedure, the type, orientation of reinforcements, sequence of plies, and the assumed or calculated mechanical properties. This information should be indicated on the drawings.

Testing

Cold Molded:

- If the structural design is based on modulus of rupture values exceeding 22% of the particular wood species' established modulus of rupture value, contact the cognizant OCMI to determine the amount and frequency of material testing required.

  Generally, properties of wood, perpendicular and parallel to the grain, are well established and material testing is not required. For most carvel construction and for the internals of cold molded wood construction the established values can be used directly; it being understood that the grain runs parallel to carvel planks and to the direction of both carvel and cold molded wood internals. However, with cold molded shell and deck plating, the cold molded wood plies in which the grain runs parallel to the ply, are generally laid at plus and minus 45^{o} to the longitudinal axis of the boat. Tests conducted by ABS Americas have determined that the ultimate strength in the principal axis of a panel laid up in such a manner is about 22% of the ultimate strength in the principal axis of a panel in which the plies are laid parallel to the principal axis. Thus, without the builder conducting material tests on the cold molded wood laminate, the modulus of rupture value to be used in the design calculations must be 22% of the particular wood species' established modulus of rupture. The boat builder always has the option to conduct testing to a recognized standard to determine the cold molded laminate's modulus of rupture as-built. In these instances, the as-tested values may be used in the calculations.

FRP

- When portions of the vessel are constructed of fiberglass reinforced plastics (FRP), contact the cognizant OCMI to determine the amount and frequency of laminate material testing required.

  Plan approval should be completed prior to beginning the vessel's construction. This means that MSC approval of the vessel's plans is based on structural calculations using assumed or calculated material properties for each laminate. Since the strength and reliability of a laminate is entirely in the hands of the fabricator and may vary greatly from one boat to the next, it is essential that these design properties are verified prior to the Coast Guard issuing the vessel a Certificate of Inspection. Preferably, test panels are either laid up as qualification test samples at the time of boat lay-up, or they are taken from hull cut-outs or plugs or hull laminate extension tabs. If test results determine that the laminates' properties are less than those used in the design, the plans and/or calculations must be appropriately updated and resubmitted to the MSC for approval.

The tests associated with the laminate properties determine the laminates' specific gravity, glass content, tensile strength and modulus, flexural strength and modulus, shear strength, and where glass content is 40% or more, interlaminar shear strength. The specific tests are as follows:

Type of Laminate	Properties	Test
Single skin	Flexural strength and modulus	ASTM D790 or D790M or ISO 178
Single skin	Shear strength, perpendicular and parallel to warp	FTMS 406 1041 or ASTM D732 85
Single skin and sandwich	Glass content and ply-by-ply analysis	ASTM D2584 or ISO 1172
Single skin and sandwich (both skins)	Compressive strength and modulus	ASTM D695 or D695M or ISO 604
Single skin and sandwich (both skins)	Tensile strength and modulus	ASTM D3039 or D638 or D638M or ISO 3268
Single skin and sandwich (both skins)	Interlaminar shear strength	ASTM D3846
Sandwich: Core to skin bondline	Flatwise tensile test	ASTM C297
Sandwich: Core material	Shear strength and modulus	ASTM C273

Plans

Check that the following plans are included in the submittal package if applicable to the vessel (in triplicate). Representative sections must be submitted when scantling plans are not available.

- ❑ Bottom construction, floors, girders, inner bottom plating, etc.

- Deck plans
- Framing plan
- Midship section - Identifying all cutouts, longitudinal stiffeners/girders that are not considered effective, and all local loadings (i.e. wheel loads, foundation loads, concentrated or distributed loads).
- Pillars and girders
- Scantling profile and decks
- Shell expansion - Identifying hull planking type, method of attachment, use of adhesives, arrangement of mechanical fasteners
- Superstructure and deckhouses
- Watertight and deep-tank bulkheads
- Miscellaneous non-tight bulkheads which are used as structural supports
- Watertight doors and framing
- Window and framing details
- Structural details of engine foundations, deck fittings, deck to hull joints, interior joints, shell details such as chine and transom, through hull penetrations, boundary angles, flanges or tapes, mechanical fasteners, panel stiffeners, brackets, openings in girders, structural intersections, tripping brackets, stanchion supports, stiffener endings, snipes, bulkhead penetrations, and cutouts
- Typical sections for areas of unusual structure
- General arrangement (for reference only)

Calculations

Ensure that the structural standard used to demonstrate compliance is:

- a standard permitted by the vessel's specific subchapter, and
- applicable to the vessel.

Check that the following structural calculations are included in the submittal package (in triplicate) If the standard chosen does not address some of the calculations, then calculations are not required for that particular aspect of the vessel's design:

- Keels, stems, and shaft struts
- Bottom shell plating and attached stiffeners
- Side shell plating and attached stiffeners
- Strength deck plating and attached stiffeners
- Longitudinal hull girder strength
- Hull transverse, torsional, and shear strength (multi-hull only)
- Watertight bulkheads and attached stiffeners
- Deep-tank bulkhead plating and attached stiffeners

- Non-tight structural bulkheads/tank boundaries and attached stiffeners
- Superstructure and deckhouse plating and attached stiffeners
- Other deck plating and attached stiffeners
- Stanchions
- Windows and framing
- Rudders
- Unusual structure requiring direct analysis (novel designs and/or connection details, hydrofoil appendages, etc.)
- Racking load calculations (large multi-level superstructures with few transverse bulkheads and/or supporting stanchions)

Structural Continuity

If longitudinally framed, check to ensure the following:

- Bulkheads, partial bulkheads or web frames are arranged to provide effective transverse rigidity and to support the ends of the superstructure or deckhouse.
- Longitudinal frames are supported by effective transverse structure.
- In general, longitudinals are continuous in way of transverse supporting members, except at transverse bulkheads where they may be intercostal provided continuity of strength and end fixity are maintained. If longitudinals are not continuous, ensure that they are not used in the longitudinal hull girder section modulus calculations.

If transversely framed, check to ensure the following:

- Deck and bottom girders are provided. Girders may be intercostal at transverse bulkheads provided continuity of strength and end fixity are maintained.
- Transverses are arranged as continuous web rings and girders are aligned with stiffeners at bulkheads. Alternatives will be specifically considered.

For all vessels, check to ensure the following:

- Where changes in thickness or structural section occur, they are gradual to prevent notches and other hard spots.
- The webs of all members are effectively attached to the shell, deck or bulkhead plating, to their supporting members, and to face bars.
- Openings in structural internal members are clear of concentrated loads and areas of high stresses.
- Openings in decks are framed to provide sufficient support and attachment for the ends of deck beams.

- Portlights below the main weather deck are of substantial construction and capable of being closed and secured watertight.
- Engines are supported and secured by substantial girders, suitably stiffened, supported against tripping and supported at bulkheads.
- The wood preservatives do not have a harmful effect on coatings or synthetic resins if used.
- The wood adhesives are of a waterproof type having the necessary durability and strength. In general, gluing wood with a moisture content greater than 18% should be avoided. In addition, joining ends of members should be avoided since it is impossible to join end grain with glue and get joints that are even 20% as strong as the wood. If an end connection must be made, a scarf or some other form of joint that gives a surface approaching side grain condition must be used.

If butt joints are used, check to ensure the following:

- Butt joints are separated as much as possible and hinge points along the vertical or diagonal are avoided. Planking butts are located between frames on proper butt blocks (in light construction with narrow strakes, they may be glued scarf joints at the frames and in construction with massive framing they may be butted on the frames).
- Butts in adjacent planks are at least 3 frame spaces (or at least 5 feet) apart for transversely framed, longitudinally planked vessels. If there is a solid strake between them they are at least 4 feet apart.
- Butts that fall in the same frame are separated by at least 3 solid strakes.
- Butt blocks are adequately sized. If the frame spacing allows it, the length is at least 12 times the planking thickness and its width at least 1 inch greater than the strake width.
- Plywood butt blocks are not used.

Check the mechanical fasteners for the following:

- Mechanical fasteners are of a material suitable for the service intended and are galvanically compatible with the materials being fastened or provided with the necessary insulation.
- The number, size, type and spacing of fasteners are adequate.
- Brass fittings are not used.
- Ferrous fasteners are hot-dipped galvanized.

- Stainless steel fasteners are used only if ALL of the following conditions are met (see ref. h):
  - They are austenitic grade at least Type 304, preferably Type 316.
  - They do not pass through wet wood, i.e. NEVER used below the waterline.
  - There is ample sealant under the head and in between mating surfaces.
  - The item being fastened is less noble than stainless.

Attachments

1. Alternative Structural Standards

Alternative Structural Standards

When at all possible a classification society standard should be followed in its entirety. American Bureau of Shipping (ABS) states unequivocally that the purpose of their standards is to express current design and construction practice in a relatively simple, comprehensive engineering format. There is no intent or assurance that their standards can do this when used with other structural analysis methods or equations. In addition, ABS cautions that it cannot be overemphasized that the design pressures and design stresses for each standard are inseparable from each other and from their strength requirements. For example, one cannot compare a standard's design pressures with those obtained from other sources without reference to the different design stresses associated with these pressures. That being said, for various reasons the engineer may discover vessels that do not "neatly" fit into one of ABS's published standards. In these cases, the designer may revert to engineering "first principle" calculations to demonstrate that the vessel has adequate safety and strength for its intended purpose. The purpose of this attachment is to give some general guidance as to what alternative structural standards may be used to form the basis of a "systematic analysis" without going into specific calculations or equations.

There are other classification societies' standards that have at one time been published and can form the basis of a "systematic analysis" used to demonstrate adequate safety and strength of a vessel. One used very often for carvel and cold molded vessels is the ABS Rules for Building and Classing Offshore Racing Yachts. Another standard applicable to large sea-going wooden vessels is the ABS Rules for Building and Classing Wood Vessels.

Many standards that address FRP vessels, such as the ABS Guide for Building and Classing Reinforced Plastic Vessels and the ABS Guide for Building and Classing High-Speed Craft, can also be adapted and used for wooden vessels. When doing so, careful consideration must be given to how the standard accounts for the directional properties of the wood, and how much credit is given to the hull plating when determining the section modulus and moment of inertia of internal stiffeners. For instance, it is presumed that carvel/strip planks are considered to resist load only in the direction parallel to the planks and offer no resistance to load in the perpendicular direction. Therefore, the section modulus and moment of inertia of an attached stiffener are those of the stiffener only. There are other legitimate adaptations that can be made such as considering a sandwich panel, that uses a core effective in resisting bending, to be a single-skin panel having a thickness equal to the total thickness of the sandwich and physical properties equal to those of the core. A systematic analysis based on engineering principles does not have to reference a classification society standard. The Marine Safety Center maintains a library with numerous references, most readily available for purchase from local bookstores, that discuss small craft designs in length. Two "classical" references[1] that walk the designer through a structural analysis are *Fiberglass Boat Design and Construction*, by Robert J. Scott, and *Marine Design Manual for Fiberglass Reinforced Plastics*, by Gibbs & Cox, Inc. Although these texts were written specifically to address the design and construction of FRP vessels, the systematic approach used in each can be followed and adapted to wooden vessels, again paying careful consideration to the anisotropic nature of the wood's material properties. These references are similar in that both use classical beam theory when sizing both the plating and the internals. Their approach differs, however, in predicting the design pressures and in the selection of appropriate safety factors. Caution must be given to resist the temptation to use one reference to predict the design pressures and then use another as a basis for selecting appropriate safety factors. For example, most references are based either on classical beam and/or plate theory. In all cases, the engineer has the option of applying the safety factor to the materials' yield or ultimate stress to define an allowable (design) stress; or to the calculated loads to define a design pressure that is much greater than anticipated. Thus, without a full understanding of the underlying theory, it is possible to pick and choose references so that you are using design pressures and stresses that do not include safety factors. At best this might result in a vessel that has unforeseen maintenance problems throughout its service life, and at worst this might result in the under-sizing of major strength members that could lead to catastrophic failure.

When doing an analysis independent of a classification standard, one must know the loads on the vessel. This is perhaps the most uncertain part of the analysis. A recent publication that can be used to predict the loads experienced by a vessel is the ABS Guide for Building and Classing High-Speed Craft. This Guide uses the work of Heller and Jasper, and takes into consideration the vessel's speed, length, bottom deadrise, displacement, and running trim when defining the bottom pressure. Besides more accurately predicting this pressure, this method also allows the designer to easily develop a speed to significant wave height relationship that can be used to define the vessel's operating restrictions. When taking these loads and applying them in classical beam and/or plate equations, the engineer also must understand when to take into consideration local wear and tear or other conditions peculiar to the vessel. Classification societies in general, take the classical theories and modify them if necessary to reflect successful service experience of existing vessels, and to account for service conditions that warrant increasing the strength requirements of particular structural members. When the engineer goes at it alone, he must also do the same.

[1] Direct reference to these texts does not constitute an endorsement by the U.S. Coast Guard. The reference is based solely on the familiarity MSC staff members have with these texts. There are numerous other texts that discuss small craft designs that may be used to form the basis of a systematic analysis.